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Late Glacial and Holocene vegetation changes in the western part of Rzeszów foothills (Sandomierz basin) based on the pollen diagram from Krasne near Rzeszów

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ABSTRACT. In 1999 in Krasne a core from peat sediments was collected to a depth of 6.45 m, using an Eijkelkamp peat sampler. The peat bog in Krasne is situated in Rzeszów foothills (south-eastern Poland), 3 km east of Rzeszów. For palynological analysis 44 samples were selected, additionally, 3 samples were dated by the radiocarbon method. The pollen diagram based on the results obtained has been subdivided into 7 local pollen assemblage zones (L PAZ). Results of the palynological analysis were used for the vegetation history reconstruction from the Younger Dryas through the Holocene, up to the Subatlantic. A clear overrepresentation of *Pinus*, present throughout the whole pollen succession, was a complicating factor during interpretation of the results. The first detectable human influence was observed in the early Atlantic and its intensity varied through the upper part of the pollen diagram. It is difficult to distinguish particular phases of settlement as the upper part of the core was strongly compressed.

KEY WORDS: pollen analysis, human impact, Holocene, SE Poland

INTRODUCTION

The Holocene vegetation history of Sandomierz basin was previously described by: Mamakowa (1962), Nalepka (1994), Bałaga and Taras (2001), and Madeja (2002). Data based on pollen analysis from Rzeszów foothills is very poor, and a major part of foothills has not been investigated floristically and geobotanically (Fig. 1).

The profile under consideration was collected during investigations for the "Detailed geological map of Poland – Rzeszów sheet" (in Polish: "Szczegółowa Mapa geologiczna Polski – arkusz Rzeszów") and was described in the geological documentation as Krasne 4. The palynological analysis was undertaken as one of the methods for age determination of the peat bog sediments. Pollen diagrams made during the investigation were also used for reconstruction of vegetation changes in the western part of Rzeszów foothills and adjacent areas.

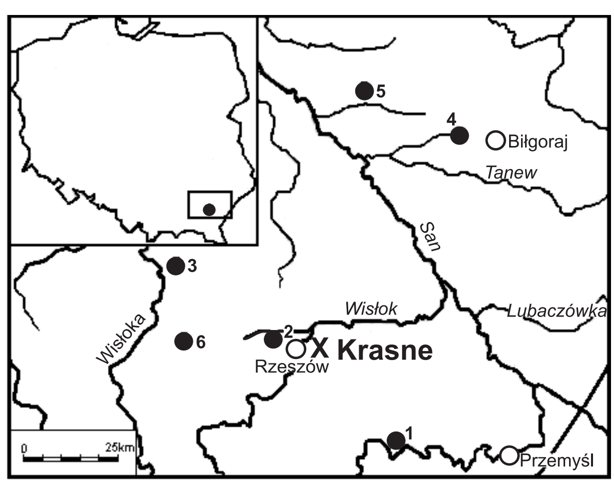

Fig. 1. Location map of the site Krasne 4 with location of selected palynological sites in Sandomierz basin (based on Mamakowa 1962). **1** – Podbukowina (outside Sandomierz basin), **2** – Świlcza, **3** – Rzemień, **4** – Obary, **5** – Imielty Ług, **6** – Wolica Ługowa

DESCRIPTION OF STUDY AREA AND PRESENT-DAY VEGETATION

The peat bog where the samples were collected is situated in the southern part of Sandomierz basin on the northern end of Rzeszów foothills (Kondracki 2002). Foothills is constructed of Miocene loams covered by periglacial alluvium and glacial and glaciofluvial sediments of the Sanian 2 glaciation advance and with loess covering the surrounding slopes at higher levels (Laskowska-Wysoczańska 1971). It reaches 240–280 m above sea level and is located between two large rivers, the Wisłoka and San. The predominant soil types of the area are Haplic Luvisols, Stagnic Luvisols and Fluvisols (Skiba & Drewnik 2003). Around 650 vascular plant taxa occur in Rzeszów foothills (Wilk 2004). Within this area human activities have caused significant changes in the structure and composition of plant communities. The fertile soils overlying the loess have been intensively exploited by farmers and shepherds since Neolithic times. Most of the forest cover was thinned out and reduced to patches in the area under study. To the north of the sampling site a belt of pine forest associated with sandy soil occurs. In the river valleys, in swampy hollows on the margins of the old river channel, occur remains of alder woods, *Carici elongatae–Alnetum* association.

Wetlands supporting a *Salici-Populetum* complex, have survived in patches on floodplain terraces of the Wisłok. Unforested communities consist of arable fields and meadow grasslands mainly of the Arrhenatheretea class.

The profile investigated was collected from a peat bog about 3 ha in area, situated in Krasne-Wólka (50°03′05″ N 22°02′23″ E; altitude 202.7 m above sea level). This bog sits on a level area at the northern foot of the loess-covered upland; it lies 6 m above a terrace of the Wisłok with rendzina soils (Rendzic-Leptosols). Below the layer of peat was found a bed of silt, which has been considered to be evidence of some kind of water body formerly occurring on the site of the peat bog (Zimnal & Malata 1999). This might relate to an older river channel (Gębica 2004) or to the outflow of groundwater springs (Z. Zimnal pers. comm.). Recently a drainage ditch was constructed near the site, resulting in drying out of the upper layers. The peat bog is covered mainly with *Phragmites australis*, *Typha latifolia,* and *Carex* spp. At the margins of the peat bog grow *Alnus glutinosa*, *Betula*, *Populus tremula*, and *Salix* sp. The closest domestic buildings are situated about 150 m away from the sampling site.

THE HISTORY OF SETTLEMENT ON SOUTH-EASTERN REGION OF RZESZÓW

Chronology of archaeological cultures occurrence is according to J. Machnik (Harmata et al. (2006).

In the earliest part of Holocene the dominant culture was the Mesolithic (10 260–6590 BP). Mesolithic communities mainly subsisted on fishing and gathering, and were significantly active in the area under consideration (Starkel et al. 2002).

The first culture is apearing in Poland from the south was the Linear Pottery culture (6500–5600 BP) proceeded by tribes of Lengyel-Polgar cycle cultures (5600–4800 BP). The distribution of Linear Pottery culture settlements in south–eastern Poland is clearly associated with a belt of fertile loess soils occurring on the so-called Fore-Carpathian Loess Plateau. Intensive farming (cultivation of wheat, barley and millet) and cattle raising was characteristic of the Linear cultures. The nearest archaeological sites from this period are situated in Rzeszów.

The next Neolithic culture that appeared in the area of the southern part of Sandomierz basin was the Funnel Beaker culture (4800–4400 BP). For this part of Poland it is partly allochtonic culture, transferred probably from the northern Germany and Denmark and developed from Mesolitic culture – Ertebølle (Kozłowski 1999).

The spread of an agricultural system based on clearance by fire, combined with cattle, goat and sheep rearing was strongly associated with this phase of settlement. In the area of the Małopolska upland Neolithic people were cultivating a few kinds of cereals, peas, lentils and flax. The forest thinning out initiated by Funnel Beaker communities was the first really significant episode of human impact on the natural environment by prehistoric people in this region.

Chronologically, the final culture of the Polish Neolithic is the Corded Ware culture

(4400–3800 BP). Extensive farming based on widespread clearance of the forest by fire, initiated by people of this culture, had begun a period of permanent changes in the natural landscape. Under such changed conditions large expanses of open vegetation developed, eminently suitable for use as pasture land (Czopek 1999). Naturally, under these conditions, people of this culture relied mainly on raising livestock. Within the Rzeszów administrative unit sites of this age have been found at Harta, Grzegorzówka, Dylągówka and Hyżne (Czopek op. cit.), and numerous further sites have been reported from south-eastern Poland. Discoveries of burial mounds in now afforested areas of foothills provide evidence for an intense occupation during the late Neolithic. Construction of burial mounds would only have been possible and practical in areas which had already been deforested at that time (Machnik 1989).

The early Bronze age is represented by the Mierzanowice culture which developed about 3800–3300 BP. The farming practices of this culture can be described as an efficient agriculture, with a significant role for sheep and cattle grazing on pastures situated relatively distant from the settlements, combined with cultivation of fields sited close to the homesteads.

A little later in the Bronze age (3300–3100 BP) the Trzciniec culture developed which primarily occupied areas that were not in use by the local Mierzanowice culture people. Settlement has been reported in all parts of Sandomierz basin. The main human activities were farming and stock raising. The most important occupation site was that found at Rzeszów-Baranówka (Czopek 1999).

The late Bronze age and the early Iron age (3100–2310 BP) were the periods when the area under consideration was occupied by people of the Tarnobrzeg culture which is a component of a wider cultural range the so-called "cinerary urn field" cultures. Settlements of the Tarnobrzeg were concentrated mainly along river valleys where occupation sites, including cemeteries, were established on higher terraces (e.g. the site at Białobrzegi). One placement of this culture was found near Krasne – in Trzebownisko (Fig. 2, Tab. 1).

A sudden collapse of settlement occupation took place at the beginning of the La Tene

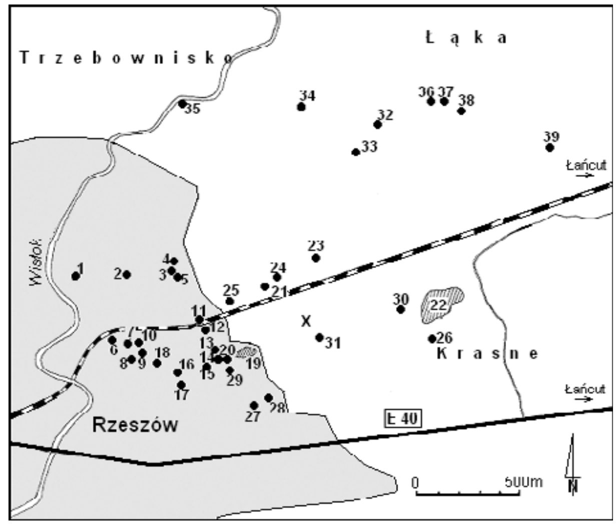

Fig 2. Location of archaeological sites (number 1–39) in the Krasne region mentioned in Table 1 (made by S. Czopek). x – investigated peat bog in Krasne

period (2310–2020 BP), resulting in the disappearance of the Tarnobrzeg culture. This is one of the most puzzling phenomena in the archaeology of the area, and presumably the reason why there are only a few finds from this period of time.

The period of dominance of the Przeworsk culture (2020–1370 BP) is also that of Roman influence. Especially during the beginning of the 1st century AD there was a real explosion of settlement, with this culture expanding to the east and the south-east. The archaeological sites seem to confirm a well-developed pattern of settlement in the larger river valleys in this region. The loess areas were also intensively settled.

The next intensification of settlement took place in the first part of the 4th century AD. There was a high density of occupation sites in the Mrowla valley (within the limits of present-day Rzeszów) and in Krasne itself.

In the 5th century AD southern Poland came under the influence of the Huns from Kotlina Karpacka. The downfall of this country in the year AD 454 caused a significant emigration of the population. During the 4th/5th centuries AD the next settlement phase took place, with Slavonic people arriving from east (Godłowski 1985).

Since the 6th–7th centuries AD Rzeszów has been existing as a settlement. From the 14th century AD until the time of Kazimierz III Wielki the whole of the former Rzeszów administrative unit was governed by the Dukes of Halicz. In 17th and 18th centuries

Table 1. List of archaeological sites and cultures from the Rzeszów–Krasne–Trzebownisko region presented on Fig. 2; gm. – gmina, Polish administrative unit

Site	Locality	Chronology
1	Rzeszów	Early Medieval
2	Rzeszów	Late Paleolithic, Neolithic, Hallstadt D, Roman period
3	Rzeszów	Neolithic, Roman period
4	Rzeszów	Early Medieval
5	Rzeszów	Roman period
6	Rzeszów	Early Medieval
7	Rzeszów	Early Medieval
8	Rzeszów	Prehistorical times
9	Rzeszów	Early Medieval
10	Rzeszów	Neolithic
11	Rzeszów	Late Medieval
12	Rzeszów	Neolithic
13	Rzeszów	Neolithic, Roman period
14	Rzeszów	Roman period
15	Rzeszów	Neolithic, Roman period
16	Rzeszów	Early Medieval
17	Rzeszów	Late Medieval
18	Rzeszów	Neolithic
19	Rzeszów – Wilkowyja	Late Paleolithic, Neolithic, Bronze age, Hallstadt, Roman period
20	Rzeszów	Neolithic
21	Załęże gm. Krasne	Unidentified coins
22	Krasne-Wólka	Neolithic, late Roman period, early Medieval
23	Załęże gm. Krasne	Prehistorical times
24	Załęże gm. Krasne	Prehistorical times
25	Załęże gm. Krasne	Early Medieval
26	Krasne gm.	Prehistorical times
27	Rzeszów	Late Medieval
28	Rzeszów	Prehistorical times, early Medieval
29	Rzeszów	Prehistorical times, late Medieval
30	Krasne-Wólka, gm.	Stone age, Roman period
31	Krasne gm.	Prehistorical times, late Medieval
32	Krasne gm.	Roman period
33	Krasne gm.	Roman period
34	Trzebownisko gm.	Lusatian culture
35	Trzebownisko gm.	Neolithic
36	Łąka gm. Trzebownisko	Roman period
37	Łąka gm. Trzebownisko	Early Medieval
38	Łąka gm. Trzebownisko	Neolithic, Roman period
39	Łąka gm. Trzebownisko	Early Medieval

AD there were numerous incursions by Tartar groups into the area, and subsequently invasions by the Swedes and Hungarians took place.

In the 18th century the population of Rzeszów increased significantly, as a result of the development of several small industrial plants, a mill and a steam tannery. Between the 1st World War and the 2nd World War the timber industry developed. Since the 2nd World War (20th century's 50s) Rzeszów has undergone massive expansion. The population has increased fivefold, and the area of the town sevenfold.

MATERIAL AND METHODS

The profile for palynological analysis was collected from the peat bog by Z. Zimnal and P. Marciniec, using an Eijkelkamp peat sampler. From the 6.45 m core samples of 1 cm^3 were collected at intervals of 5 cm. From a total number of 137 samples, 44 were used for palynological analysis.

The organogenic sediment was prepared for analysis using the modified Erdtman acetolysis (Faegri et al. 1989), and with addition of *Lycopodium* tablets (Stockmarr 1971). HF treatment was applied to those samples containing mineral material (Moore et al. 1991). Every sample was counted until a total of about 350–450 AP pollen grains was reached. The percentages were calculated on the basis of a pollen

Table 2. Radiocarbon dates in the profile Krasne 4 (Pazdur 1999)

Depth (cm)	Lab. No.	Date ^{14}C BP
93–97	Gd-10949	4250±100
460	Gd-10951	9990±210
574	Gd-10952	10 860±230

sum including both trees with shrubs (AP) and herbs (NAP). Pollen grains of aquatic and mire plants, Cyperaceae and spores were excluded from this sum. The results obtained were presented as pollen diagrams drawn using the POLPAL for Windows software (Walanus & Nalepka 1999).

Three samples were dated, using the radiocarbon method (Tab. 2), at the Radiocarbon Laboratory of the Silesian Technical University in Gliwice (Pazdur 1999).

SEDIMENT DESCRIPTION

Depth (cm)	Lithology
0–40	black peat, decomposed
40–325	black to dark brown peat, with numerous non-decomposed brown plant remains
325–479	black to dark brown peat with numerous non-decomposed brown plant remains and an admixture of silt and fine grains of calcium carbonate (up to 1 mm ∅)
479–490	calcareous sinter (carbonate grains 1–2 mm ∅, dark brown–"white")
490–560	black to dark brown peat with plant remains with an admixture of calcium carbonate
560–572	very dark brown organic silt
572–577	black to dark brown peat with plant remains
577–600	dark brown to black organic silt with an admixture of calcium carbonate grains
600–610	grey to dark brown silt with single plant fragments
610–635	grey to light blue sandy silt with individual plant fragments
635–640	grey to light blue, poorly sorted sand (mainly fine-grained)

DESCRIPTION OF LOCAL POLLEN ASSEMBLAGE ZONES

The pollen diagram (Fig. 3) is divided into local pollen assemblage zones (L PAZ) in the sense of Birks (1979, 1986) and Janczyk-Kopikowa (1987) on the basis of visual analysis of pollen curves. The description of local pollen assemblage zones is presented in Table 3 (see p. 460).

VEGETATION HISTORY

Vegetation history in the Krasne area has been based on distinguished local pollen assemblage zones and the available radiocarbon datings. Its presented in the periods treated as chronozones (Mangerud et al. 1974).

KR4/1 L PAZ. There were fluctuations in abundance between pine and pine-birch forests and shrinking patches of steppe-tundra communities. The latter were characterized by taxa indicating a cool and dry climate, e.g. *Betula nana*, *Saxifraga oppositifolia* type, *Selaginella selaginoides*, and *Pleurospermum austriacum*. Mamakowa (1962) has shown that the present-day distribution range of *Pleurospermum* is restricted to areas with low mean January temperatures (–35 to –2°C). Representatives of the genera *Salix* and *Populus* were abundant in this period. *Salix* in particular here attains its maximum representation in the diagram and was clearly a very significant component of forests and wetland scrub at this time. High percentages of *Larix* suggests that larch was playing an important role in forests in the Krasne area. The occurrence of *Juniperus* and other heliophytes possibly show the presence of small patches of xerophile vegetation amongst open woodland. A very chracteristic phenomenon of this period is the overrepresentation of *Filipendula*. The rise of *Filipendula*, which has been noted in numerous diagrams from south-eastern Poland, often occurs at a time of increased climatic warming and humidity. According to Paus (1992) the arrival of *Filipendula* shows that the mean July temperature was not lower than 8–9°C. On the other hand, such enormous pollen percentages probably resulted from the presence of a whole anther in some pollen samples. Individual pollen records of aquatic taxa (*Potamogeton*, *Potamogeton* subgen. *Coleogeton*, *Ranunculus flammula* type and, *Myriophyllum verticillatum*) demonstrate that there was open water present at the sampling site. High percentages of NAP (including high Chenopodiaceae and *Artemisia*) and numerous meadow taxa show that there were significant open areas in the forests.

This zone appears to represent the Younger Dryas chronozone.

KR4/2 L PAZ. In this zone *Pinus* increased in abundance within forest communities, whilst *Larix* decreased and *Betula* became significantly restricted in its occurrence. Around 10 000–9000 years BP elm (*Ulmus*) entered Poland from the south-east (Ralska-Jasiewiczowa 1983, Zachowicz et. al 2004). As the forest became denser and shading of the

Table 3. Krasne 4. Description of local pollen assemblage zones

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
KR4/1	*Betula-Larix-Salix*	600–480	Low levels of AP, the curve shows significant fluctuations. *Pinus* pollen dominates. Maximum values for diagram were achieved *Larix* (up to 1.8%), *Betula* (max. 11.3 %), *Salix* (max. 8.4 %), *Juniperus* and *Populus*. At depth 520 cm a few *Betula* cf. *nana* grains were found. In NAP typically Cyperaceae values exceed those of Poaceae. *Filipendula* pollen (max. 62.4 %) appears to be overrepresented. Relatively high percentages of *Artemisia* (max. 3.6 %) were recorded. Among the taxa associated with the Late Glacial single grains of *Pleurospermum austriacum*, *Saxifraga oppositifolia* type, *Selaginella selaginoides*, and *Helianthemum* were found. Grassland taxa, such as *Rumex*, *Hypericum perforatum* type, *Sanguisorba officinalis*, *Ranunculus* type, and *Thalictrum* were represented in relatively high numbers
KR4/2	*Pinus*-Poaceae-Filicales monolete	480–410	Increase of *Pinus* (which dominates the AP), Poaceae pollen percentages and Filicales monolete spores; decreases in the percentages of *Larix*, *Filipendula*, *Betula*, *Juniperus*, and *Salix*. At 470 cm depth a sustained rise of *Ulmus* percentages begins (0.2 to 1.2 %). In the upper part of the zone the frequency of *Corylus* increases. The AP curve shows a sustained increase from 470 cm depth. NAP are represented by Poaceae, reaching 33.7%. Cyperaceae percentages fall to very low values (12.4 to 2.2%). Filicales monolete spores reach very high percentages (up to 55.6%)
KR4/3	*Pinus-Corylus*	410–330	High percentage of corroded sporomorphs (up to 60.5%). Values for *Pinus* remain at a very high level (over 80%). *Corylus* shows a continuous increase (0.6 to 6.0 %). The AP sum is about 85%. *Picea abies* grains are regularly observed (max. 2%). *Alnus* and *Fraxinus* percentages increase in the upper part of the zone. *Ulmus* is increasing although at 360 cm depth no grains were noted. At 335 cm two grains of *Hedera helix* were found. Among the NAP Poaceae dominate together with Cyperaceae (which generally increases). Filicales monolete spores still dominate and the presence of *Pteridium aquilinum* was recorded (0.9 %)
KR4/4	*Ulmus-Corylus*	330–242.5	Begins with a characteristic decrease of *Pinus* percentages and a clear increase of *Corylus* (max. 10.3%) and *Ulmus* (max. 5.4 %) frequence. *Quercus*, *Tilia*, *Fraxinus*, *Alnus*, and *Betula* percentages increase. Among the NAP Cyperaceae and Poaceae dominate and increase their percentages. Single grains of cereals (*Triticum* type and *Hordeum* type) were observed. Among ferns Filicales monolete continue to dominate
KR4/5	*Picea-Quercus-Pteridium*	242.5–90	*Pinus* dominates, but *Picea* reaches its highest percentages in the diagram. Relatively high values of *Quercus* were noted (max. 11.6%). *Betula* increases (up to 8.5%), *Corylus* remains at the same level (max. 7.0%) through this zone, and *Alnus*, *Ulmus* and *Tilia* also show little change. *Fraxinus* values are low but with a clear maximum at the beginning of the zone. At 130 cm *Acer* reaches its maximum percentage in the diagram (2.0%). Single pollen grains of *Hedera helix* (220 cm) and *Vitis vinifera* (200 cm) were recorded. AP percentages increase at the beginning of the zone and decrease to 80% in the upper part. Among NAP Cyperaceae and Poaceae dominate. Among crop indicators grains of Cerealia, *Avena* type, *Hordeum* type, and *Fallopia convolvulus* type, an arable weed, were found. Filicales monolete values clearly decrease. Highest percentages of *Pteridium aquilinum* (max. 5.9%) in the diagram are recorded
KR4/6	NAP-*Alnus-Carpinus*	90–47.5	*Carpinus* and *Alnus* percentages increased significantly (*Carpinus* – max. 9.1%; *Alnus* – 16.5% in the upper part). *Pinus* and *Picea* systematically decrease. In the upper part *Abies alba* occurs. *Corylus* and *Tilia* remain at values similar to those in zone KR4/5. *Quercus* percentages remain at a constant, low level. In the younger part a clear decrease was observed for *Ulmus*, *Fraxinus* and *Betula*. This zone is characterized by a systematic increase of NAP. Among herbs, Cyperaceae, Poaceae and Asteroideae undiff. continue to dominate. Among crop taxa the presence of Cerealia was observed (with a continuous curve above 70 cm depth). One grain of *Hordeum* type was noted (60 cm depth). Among ferns Filicales monolete still dominate, with significant values at some levels; *Pteridium aquilinum* occurs sparsely
KR4/7	NAP-*Alnus*	42.5–2	*Alnus* dominates. Reduction of *Pinus* values to 28%, then an insignificant increase in the upper part. *Picea* percentages decrease (min. 0.3 %), and *Abies* grains are more numerous compared to values in zone KR4/6. In the youngest part of the zone *Fraxinus*, *Ulmus*, *Tilia*, *Quercus,* and *Betula* percentages are very low. *Fagus sylvatica* pollen occurs with increasing frequency but with a continuous curve only from 25 cm depth. From 14.5 cm depth there is also a continuous *Sambucus nigra* type curve, not exceeding 1%. Rise of the NAP curve, reaching its maximum of 50%. The dominance of Poaceae and Cyperaceae increases, and a sudden rise in Asteroideae undiff. is evident. In this zone *Plantago lanceolata* appears with increasing frequency. Cerealia grains become more abundant, reaching 2.3% at 25 cm depth, at several levels single grains of *Triticum* type (35 cm), *Hordeum* type (35 cm) and *Secale cereale* (from 25 to 7 cm) were observed, accompanied by a particularly significant collection of weeds and ruderal plants, such as *Urtica* (up to 8.6 %), Chenopodiaceae, Cichorioidae and others. Ferns present are mostly by Filicales monolete, but with *Pteridium aquilinum* found in almost all samples

forest floor increased, so did the abundance of ferns (Filicales monolete), but heliophilous taxa, such as *Artemisia* and Chenopodiaceae, decreased. Also the diversity of herbaceous taxa present declined.

Open water almost disappeared, only a single pollen grain of one typically aquatic plant (*Potamogeton* subgen. *Coleogeton*) was found. The pool had slowly been overgrown by *Phragmites*, accompanied by *Typha latifolia* and *Thelypteris palustris*. The increase of corroded spores may be evidence for a fall in the level of groundwater.

This zone probably corresponds to the Preboreal chronozone.

KR4/3 L PAZ. In this period the forest layer became still denser (AP increase). *Pinus* remained the absolute dominant of the forest communities with *Betula* clearly displaced by *Ulmus* in areas of mixed forest. Throughout the whole Boreal period a successive increase of *Ulmus* is visible in forest communities (except at 360 cm). Together with *Ulmus*, spruce (*Picea abies*) appeared. A restricted presence of lime, *Tilia*, can be seen. From now *Tilia* occurred regularly in this zone. The mixed forest brushwood comprised of hazel (*Corylus*), with bracken (*Pteridium aquilinum*) in pine forests with enough light reaching the floor. The existence of open areas is also confirmed by the presence of *Artemisia*, which was more frequently noted in the older part of the zone. The herb layer of the forest supported a rich fern flora (Filicales monolete). Alder (*Alnus*) together with ash (*Fraxinus*) and elm (*Ulmus*) started to invade the lowest river terraces that, until then, had been occupied by carr and forest dominated by willows (*Salix*) and poplars (*Populus*). The occurrence of ivy (*Hedera helix*), although very sparse, is sufficient to infer a significant improvement of climate conditions, since, for flowering and fruiting, this plant demands a mean temperature of the coldest month not lower than –2°C, and the warmest above +13°C (Iversen 1944, Zagwijn 1994, Jackomet & Kreuz 1999).

This zone may correspond to much of the Boreal chronozone.

KR4/4 L PAZ. This zone begins with a decline of *Pinus* and a corresponding rise of thermophilous deciduous trees e.g. *Ulmus*, *Quercus*, *Tilia*. This indicates the enrichment of the diversity of the forests, particularly with deciduous species, although to the north of Krasne, where the soil is sandy, *Pinus* continued to dominate. *Corylus* significantly increased in abundance, and this taxon dominated the shrub layer of widespread deciduous forests, shading out the heliophilous *Betula* and *Pinus* seedlings. In the trunk space of the deciduous and mixed forests ivy (*Hedera helix*) found its most favourable growing conditions. *Alnus* and *Fraxinus* became increasingly frequent in wetlands and alder woodland. High percentages of Poaceae and an increase in meadow taxa (*Rumex*, Asteroideae undiff., Cichorioideae undiff., Brassicaceae) indicate the enlargement of open areas. The level of the groundwater rose and small lakes were formed with shores overgrown with Cyperaceae, *Phragmites*, *Typha latifolia*, *Sparganium*, and *Thelypteris palustris*.

This zone probably responds to the younger part of the Boreal (below 307.5 cm depth) and in its upper levels to the older part of the Atlantic chronozone.

KR4/5 L PAZ. During this zone disruptions of the forest took place as a result of fires, as demonstrated by the increased occurrence of charcoal on the pollen slides. These disruptions were probably human-made clearances to provide new areas for crops, particularly cereals, probably including barley (*Hordeum*) and oats (*Avena*), together with *Artemisia* and Chenopodiaceae, and also for pastures and meadows. This kind of phenomenon can be seen in the pollen diagram at 235 cm depth (and to a lesser extent at 175 cm). *Ulmus*, *Tilia*, *Corylus*, and *Quercus* percentages clearly decrease at that time. Heliophilous species such as *Pteridium aquilinum* and *Artemisia* invaded abandoned fields and pastures, followed by colonisation by heliophilous wind-dispersed pioneer trees (*Betula* and *Populus*). Forest destruction was least for wetlands and alder forests as the lowest terraces held little attraction from an economic point of view. Apart from *Pinus*, a very significant role in this zone was played by *Quercus* and *Picea*. The latter indicates a cooler and more humid climate and is generally regarded as a component of subboreal forests. In the younger part of this zone maple (*Acer*) was very clearly present in the forests.

The lower part of the zone (below 175 cm depth), belongs to the Atlantic chronozone and the upper part most probably corresponds to Subboreal chronozone.

KR4/6 L PAZ. In this part of the pollen diagram declines of *Picea*, *Ulmus* and *Quercus* within the forests are visible together with progressive decrease of *Pinus*. The increasing humidity of climate resulted in a marked expansion of *Alnus* to its maximum abundance, and aquatic and mire taxa, such as *Typha latifolia* and *Phragmites* increased. In this zone, hornbeam (*Carpinus betulus*) appeared in the vicinity of this site. Apparently, it did not play such a significant role in the forest, as at other sites investigated from Sandomierz basin, e.g. Imielty Ług, Obary (Mamakowa 1962). A little later than *Carpinus*, silver fir (*Abies alba*) appeared. In zone KR4/6 a progressive increase of herbaceous taxa began. Asteroideae undiff., Brassicaceae, and Cichorioideae undiff. began to play an increasingly significant role in open vegetation communities, together with Poaceae and Cyperaceae. The expansion of areas under cultivation is visible from the middle of zone KR4/6 zone, recorded by the continuous presence of Cerealia, including individual records of *Hordeum* type.

This zone can be recognized as belonging to the younger part of the Subboreal chronozone.

KR4/7 L PAZ. Within this youngest zone there was clearly a more significant deforestation of the area under consideration. Among significant new features was the continuous and persistent presence of beech (*Fagus sylvatica*) at a low level, and to a lesser extent of *Abies alba*. It is difficult to draw conclusions about the presence of any beech-fir forest in this area (even in small fragments) on the basis of such scant data. A similar situation has been reported it the diagrams from Świlcza (Mamakowa 1962) and Wolica Ługowa (Madeja 2002, Starkel et al. 2002) where these species occurred at a low frequency. In neighbouring areas *Fagus* percentages remained above 1% around 5000 BP onwards (Latałowa et al. 2004). In the Krasne 4 diagram (Fig. 3) such percentages were observed only at 17 cm depth, in the Subatlantic, after 2500 BP. *Abies alba* frequency in the southern part of Sandomierz basin was around 0.1–0.5% (Obidowicz et al. 2004) since 5000 BP, and the first *Abies* grains were observed in the Krasne 4 diagram (Fig. 3) later than 4250 BP. However, cores elaborated by Mamakowa (1962) were collected by Hiller's peat sampler which contaminates lower part of core with material from the upper parts (Aaby & Digerfeld 1986), so the first appearance of *Fagus* and *Abies* can not be reliable, especially in the range of 0.1–0.5 %. Among other trees *Ulmus* disappeared and *Tilia* decreased in frequency. There was a drastic decline in *Picea abies*. *Quercus* pollen values did increase at this time, but not significantly, so perhaps there was some development of formation of Pino-Quercetum type woodland. In marshy areas *Alnus* clearly dominated right through this zone. From 21 cm depth forest clearance was intensified. Some forest was replaced by elder scrub (*Sambucus nigra*). In the expanding open communities there was a greater diversity of herbaceous taxa recorded. Poaceae remain at high levels of abundance, which provides evidence for a high proportion of meadowland and pasture in the surrounding district Asteroideae and Cichorioideae increased in frequency. The importance of arable cultivation increased in this zone, with crops, particularly Cerealia, reaching their maximum values in the diagram. *Secale cereale*, *Hordeum* type, *Triticum* type, and cornflower (*Centaurea cyanus*), a characteristic weed of cereal fields, have all been recorded. Additionally, in the upper part of the profile, buckwheat (*Fagopyrum esculentum*) was also present. *Artemisia*, Chenopodiaceae, *Plantago lanceolata*, and *Urtica* represented weeds and other synanthropic plants. The presence of nettles (*Urtica*) might be interpreted as connected to nitrogen-rich sites accompanying human occupation and a consequent eutrophication of area round the peat bog, however, *Urtica* could also have occurred in the herb layer of alder woods and wetlands. In this zone spores of two liverwort species were found: cf. *Anthoceros punctatus* and *Phaeoceros laevis* which often occur on ploughed stubble fields in autumn (Rejment-Grochowska 1966).

This zone probably corresponds with the Subatlantic chronozone.

ANTHROPOGENIC ACTIVITY RECORDED IN POLLEN DIAGRAM

The first definite records of Cerealia and *Avena* type pollen occur at 220 cm depth. Slightly lower in the profile (235 cm) the *Ulmus*, *Tilia*, *Quercus*, and *Corylus* curves show a decline, with *Betula* and *Populus* increasing. This indicates a Neolithic settlement of uncertain cultural type, of which archaeological traces were found at Krasne-Wólka near the peat bog under investigation. The increase in *Pteridium aquilinum* spores and charcoal concentrations, starting at 235 cm depth, suggests the beginning of a fire-clearance economy. This phenomenon can be linked either to the impact of the Linear Pottery culture, or of the later Lengyel-Polgar cycle cultures people, who occupied loess areas, or to the beginning of the Funnel Beaker culture occupation. The next episode of *Ulmus* decline took place at 175 cm depth. It can be correlated with the *Pteridium aquilinum* maximum and with another increase in charcoal concentration. This event may be associated with impacts of the Funnel Beaker culture.

There are no precise absolute dating for the Neolithic archaeological remains, so that it is difficult to assign the episodes recorded in the pollen diagram to any particular culture. The high representation of *Pteridium aquilinum*, together with the increased concentration of charcoal, observed from 235 cm to 100 cm depth, suggests the continuous presence of Neolithic people in this area. Above 70 cm depth there is evidence for a decline of deciduous tree populations, apart from expansion of alder into marshy areas. This phenomenon is linked to the continuous and significant rise of herb taxa. This may reflect the impact of Bronze age cultural activity, although there is no archaeological evidence (Tab. 1) from this period in the near neighbourhood (Starkel et al. 2002). Evidence for the continuous growth of cereal crops begins at 70 cm depth, together with indications of the presence of a barley field near the peat bog. During the time represented by the upper 30 cm of peat intensification of cereal cultivation took place. Where cereal pollen can be identified more closely, barley and wheat are suggested, but during this period regular cultivation of rye (*Secale cereale*) began. In Poland rye is believed to have become widespread first as a weed of cereal cultivation during the Hallstatt period and then to have been grown as a monoculture during the Roman period (Wasylikowa 1983, Lityńska-Zając & Wasylikowa 2005). Its maximum frequency in this diagram is 1% (at 7 cm depth), which corresponds to the early Medieval or a later period in comparison with isopollen maps (Okuniewska-Nowaczyk et al. 2004). Cultivation of buckwheat (*Fagopyrum esculentum*) is evidenced by a single pollen grain. Cultivation of this crop peaked in the 17^{th} century, but later it became less popular and the area assigned to its cultivation shrank (Podbielkowski 1992). The development and expansion of meadowland and pasture in parallel with agricultural fields at this time was discussed earlier, as were possible impacts of human occupation in terms of local eutrophication, resulting from inputs of nitrogen compounds.

Abandoned places were settled with *Artemisia* and Chenopodiaceae representatives, and *Corylus avellana* and *Sambucus nigra* shrubs were appearing on subsequent stages of the succession.

As fertility declined, fields might be abandoned, leading to colonisation by *Artemisia*, Chenopodiaceae and other weed species. Scrub colonisation by *Corylus avellana* and *Sambucus nigra* would have been the next stage in succession. The earlier widespread practice of clearance by fire had largely disappeared by the time of the upper zones KR4/7 and KR4/8 (i.e. after ca. 4250 BP), since both the abundance of *Pteridium aquilinum* spores and charcoal concentrations decreased.

DISCUSSION

The first difficulty in interpretation during the analysis of diagram is the assignation of KR4/1 zone to the Younger Dryas chronozone. Apart from increase of *Filipendula* percentages (560–500 cm) associated to the end of the Late Glacial and the early Holocene (Miotk-Szpiganowicz et al. 2004a), many factors suggest that KR4/1 is connected to this chronozone. The first reason is occurrence in this zone taxa related with steppe-tundra and steppe-forest communities like *Larix*, *Betula nana*, *Saxifraga*, *Pleurospermum austriacum*, and *Selaginella selaginoides*. The second reason is ^{14}C dating dated at 10 860±230 BP, which sustain theory about Late Glacial origin of this zone. Despite of this, in some diagrams, we have evidences of occurrence increasing curve of *Filipendula* pollen in Younger Dryas, e.g. in Świlcza (Mamakowa 1962), in Doły Jasielsko-Sanockie, in Tarnowiec and Roztoki "a" (Harmata 1987). Never before, in diagrams from this part of Poland, was noticed so huge abundance of *Filipendula* grains in Younger Dryas

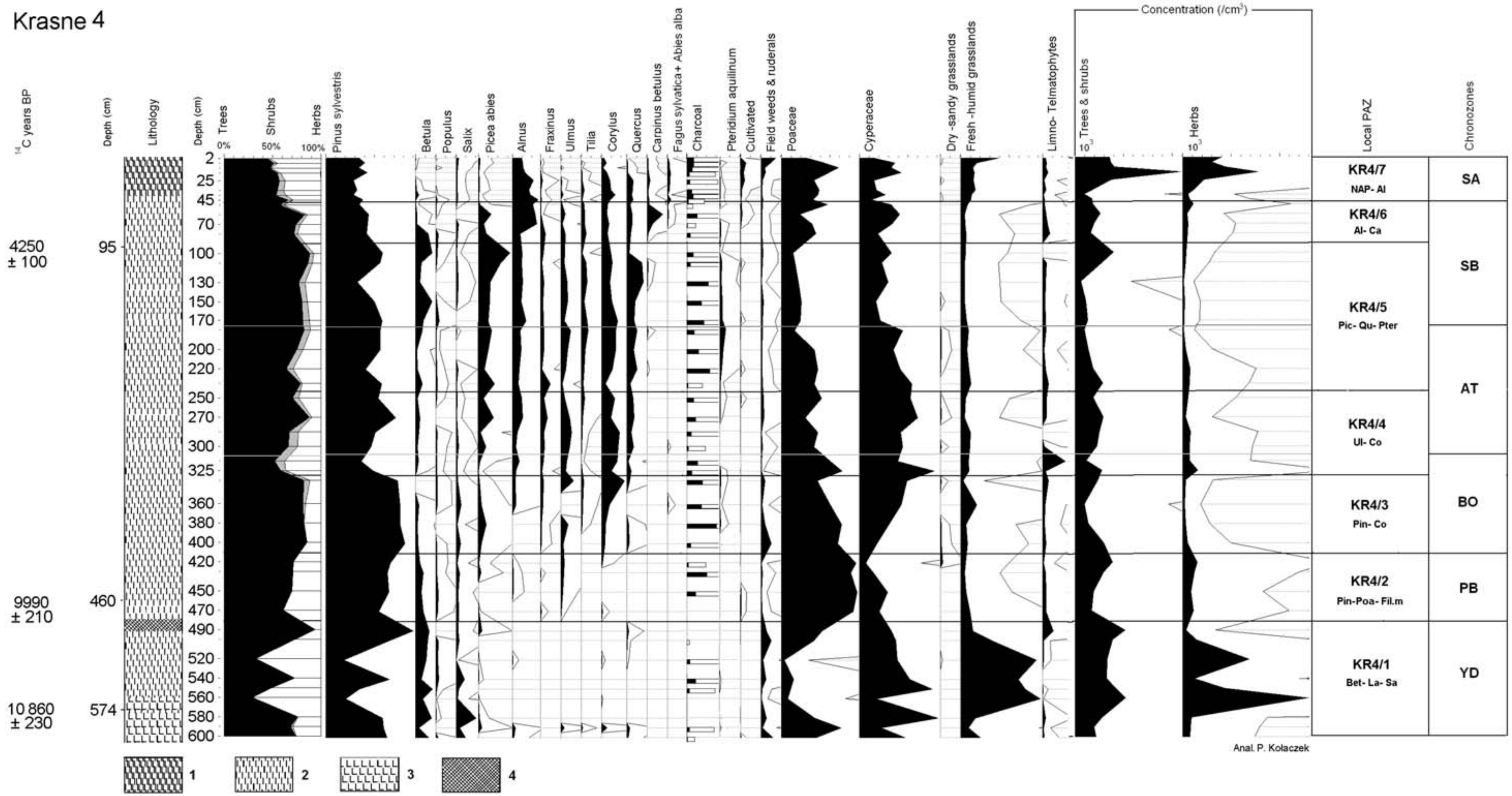

Fig. 4. Simplified forest structure, human impact and pollen concentration diagram. Percentages of all tree, shrub and herb pollen taxa are calculated from the total pollen sum, excluding *Pinus sylvestris*, Cyperaceae, Pteridophytes and Limno-Telmatophytes. **1** – peat, strongly decomposed, **2** – peat, slightly decomposed, **3** – silt, **4** – calcareous sinter

chronozone (it can be effected by remains of anthers in the material).

Also, radiocarbon dates can sometimes be unreliable in determining the absolute age of such sediments; for example in the Wolica Ługowa profile, sediments from a similar depth significantly differed in age, depending on the laboratory at which the samples were dated (Madeja 2002). In the profiles with high amount of $CaCO_3$ there is a possibility of overestimation of the date resulting of the phenomenon called the reservoir effect, which is a lower $^{14}C/^{12}C$ ratio in lake water than in atmosphere (Olsson 1986). The sample dated at 10 860±230 BP comes from silt so it might have been contaminated by dissolved in water old carbonate, but sample dated at 9990±210 comes from peat (460 cm) above calcareous sinter (479–470 cm), so it is probably not contaminated by old carbonate and confirm property of the boundary between Younger Dryas and Preboreal at 480 cm.

The next difficulty faced during interpretation of this diagram was to determine the boundary between the Boreal and the Atlantic periods. The principal characteristics to distinguish those two chronozones are: 1) the maximum of the *Corylus* curve recorded in the younger part of the Boreal (Latałowa 2003, Miotk-Szpiganowicz et al. 2004b) and 2) the maximum of the *Ulmus* pollen curve occurring within the Atlantic (Zachowicz et al. 2004). In this diagram, both the *Ulmus* curve maximum and the *Corylus* curve maximum occur almost simultaneously (Figs 3, 4). Additionally, in Atlantic chronozone in diagram, curves of *Tilia* and *Quercus* show significant increase characteristic for this part of Holocene (Latałowa 2003, Tobolski 2004).

The description of the vegetational development that took place in the Krasne area from 5000 BP until the present day is complicated by strong compaction of the sediments in the upper part of the profile. According to the radiocarbon dating, the upper 95 cm of the profile were deposited in around 4250 years (assuming that no erosion has taken place towards the surface).

The absence of any beech-fir forest developing during the Subboreal and the low values of hornbeam (*Carpinus*) are also a very interesting problems in this area. A similar situation has been described from the Świlcza (Mamakowa 1962) and Wolica Ługowa (Madeja 2002, Starkel et al. 2002) pollen diagrams. In both the latter diagrams mentioned above interpretation was also made difficult by a clear overrepresentation of *Pinus* pollen. In the case of the Świlcza diagram, this situation resulted from the fact that the peat bog is located on sandy ground with *Pinus* dominating since the beginning of the Holocene. It was difficult for other trees to become established in this area. The peat bog in Krasne is situated on the northern border of Rzeszów foothills where fertile loess soils dominate, so that the soil factor was not the main reason that determined the poor representation of beech and fir. Possible significant corrosion of pollen material in KR4/6 and KR4/7 zone had disturbed real view of relationship in vegetation history at upper part of the profile. We also can not exclude the occurrence of a hiatus, however, curves do not show this phenomena visibly. To resolve this problem further geobotanical and palynological studies are necessary.

CONCLUSIONS

This pollen sequence records vegetational history of the Krasne area from the Younger Dryas through the Holocene until the Subatlantic chronozone. The age of the lower part of profile is confirmed by radiocarbon dating. The diagram is difficult to interpretate because of poor preservation of pollen material and a clear overrepresentation of *Pinus*, which affects the percentage curves of other taxa. The first detectable human influence was recorded during the early Atlantic, and its intensity varied in the upper part of the pollen profile. However, it is difficult to distinguish particular phases of settlement. The pollen profile from Krasne 4 is the first, that presents the whole Holocene history of vegetation in the western part of Rzeszów foothills.

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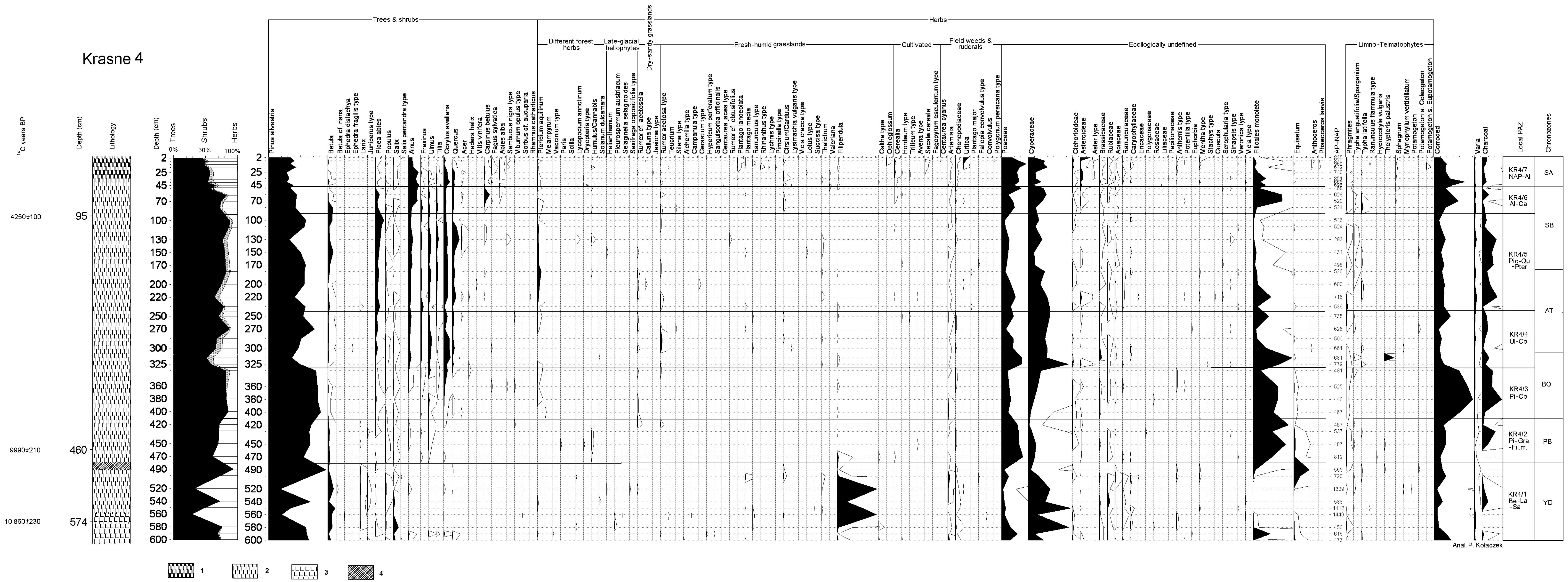

Fig. 3. Percentage pollen diagram from Krasne 4. Percentages of all tree, shrub and herb pollen taxa are calculated from total pollen sum excluding Cyperaceae, Pteridophytes, Limno-Telmatophytes. **1** – peat, strongly decomposed, **2** – peat, slighly decomposed, **3** – silt, **4** – calcareous sinter